HamSCI Solar Eclipse QSO Party (SEQP): Observations & Modeling on Ionospheric Effects

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Total Solar Eclipse April 8, 2024

Data: Over 52 million logs from ham radio networks: PSKReporter, WSPRNet, and RBN

Model: PHaRLAP raytracer with SAMI3 ionospheric densities

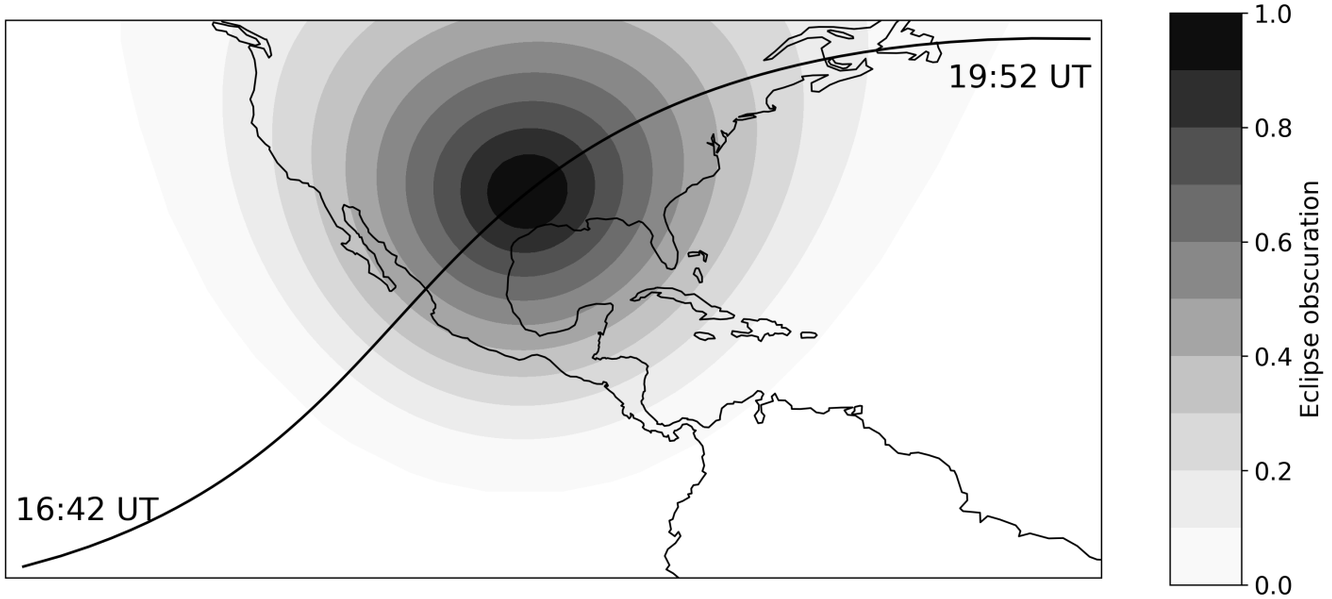
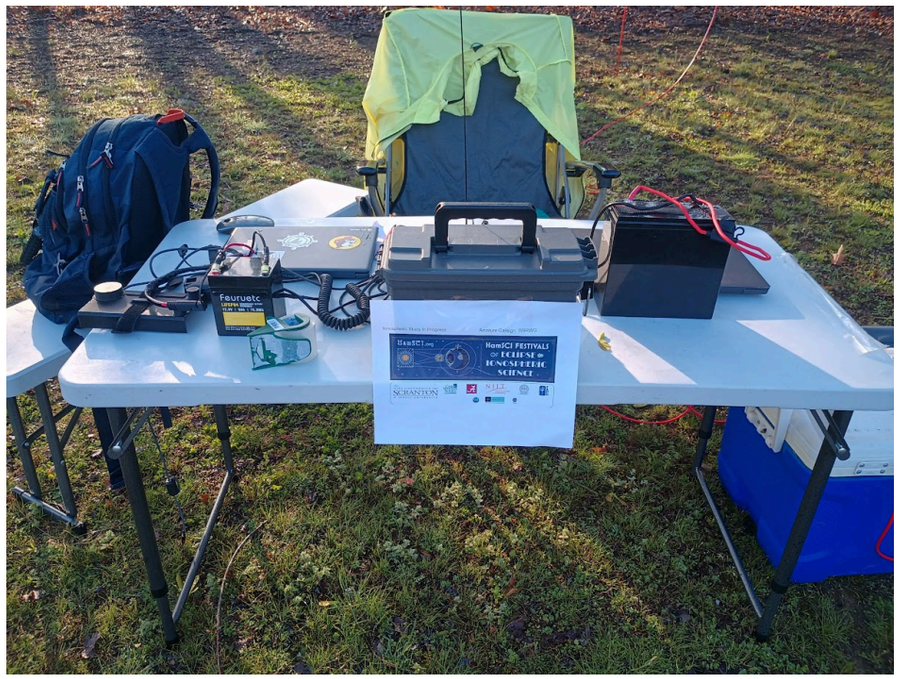


Fig: eclipse track

W1KU-Great Woods Center for the Arts, Columbia



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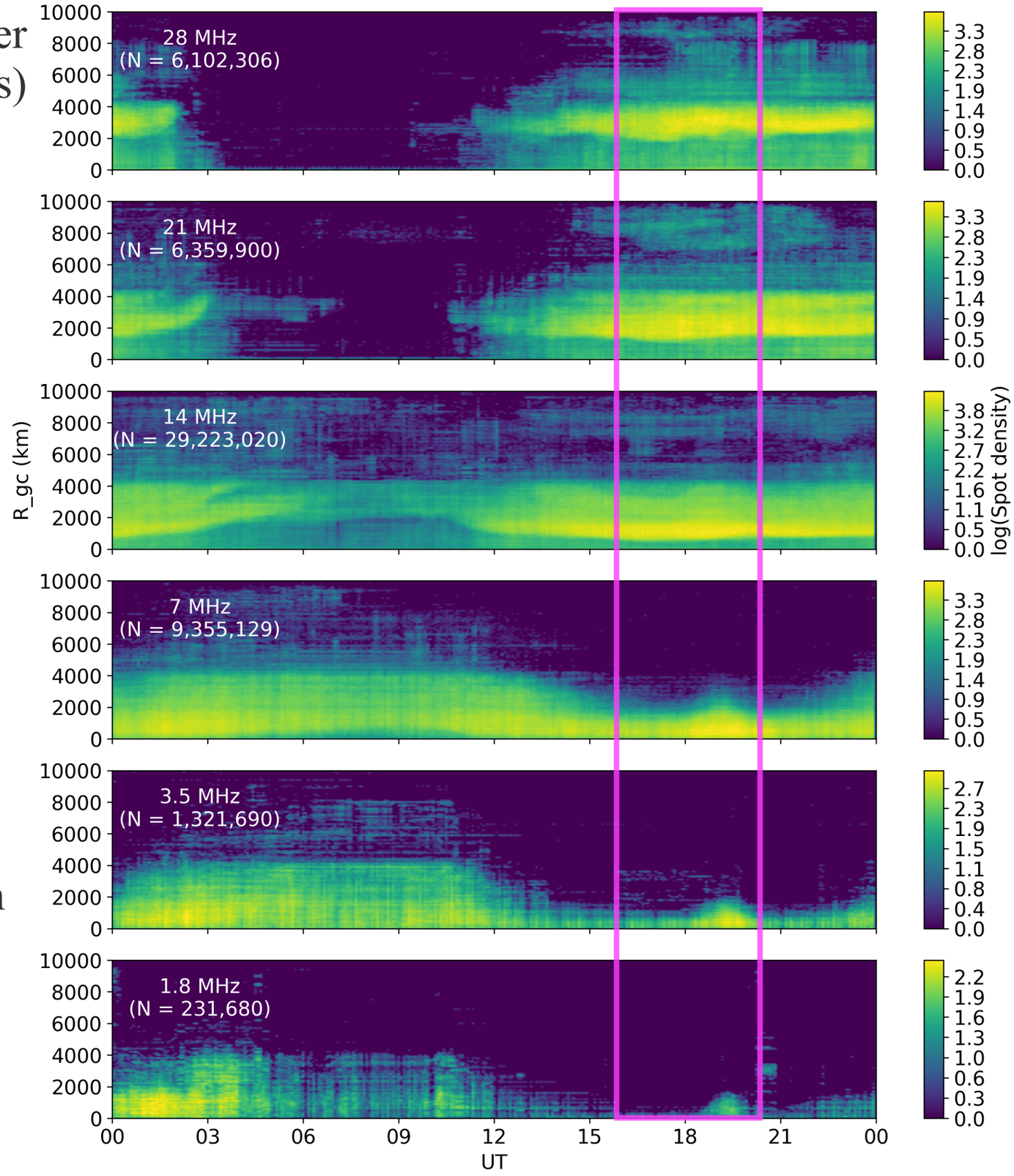
Spot Density

Fig: Ham Radio communications over CONUS (Contiguous United States)



- Eclipse effects observed on multiple frequency bands (*rectangular box*)
- Enhanced propagation during eclipse, suggests a reduction in D-region absorption

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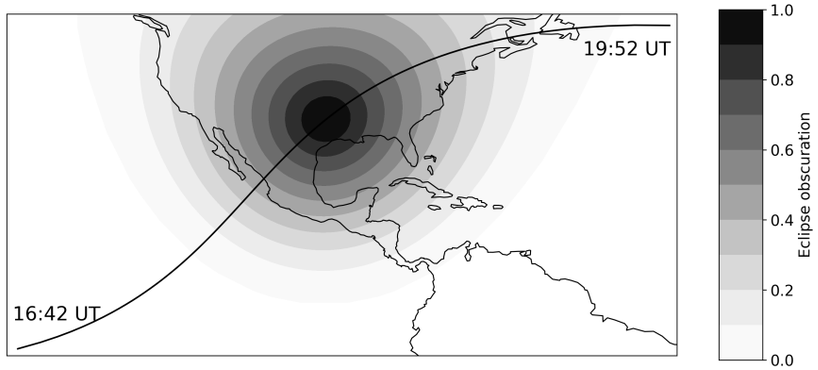
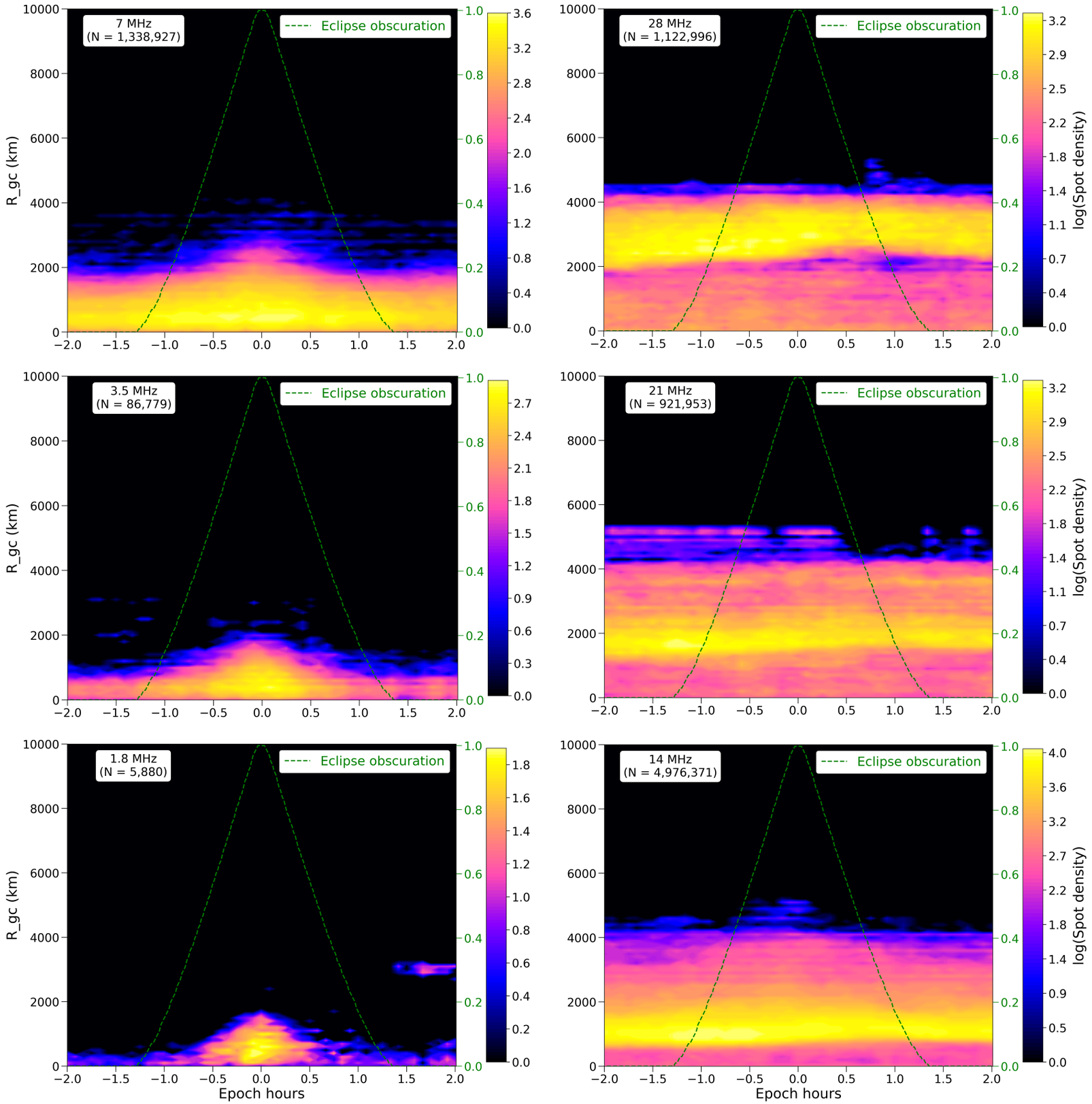
Epoch Analysis

Fig: Epoch analysis with Tx-Rx in CONUS





1.8 - 7 MHz (160 - 40 m):

- increase in range of communications
- symmetric response to eclipse

14 - 28 MHz (20 - 10 m):

- increase in range of communications
- delayed response to eclipse

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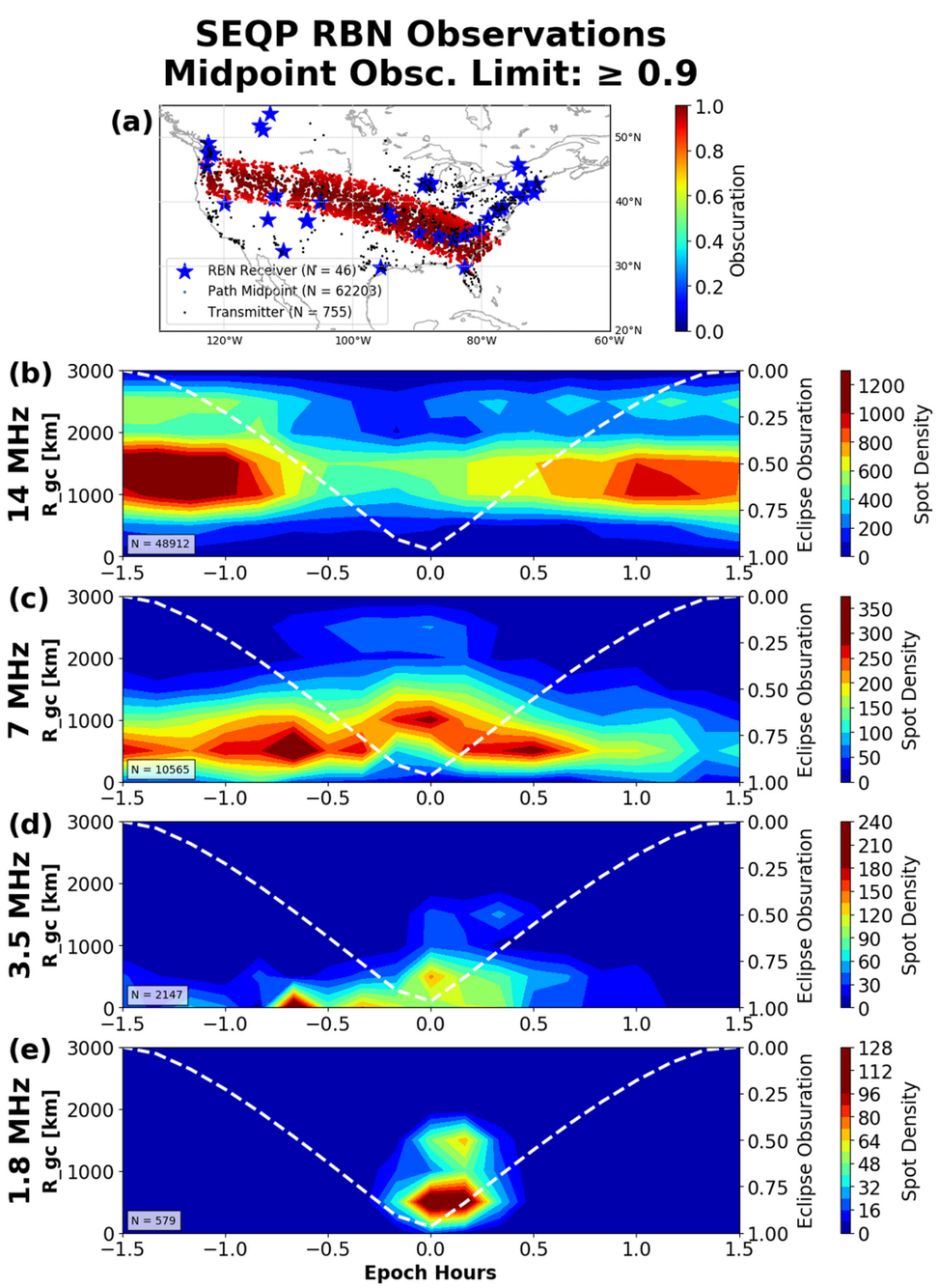
Comparison: Eclipse 2017 & 2024

August, 21 2017

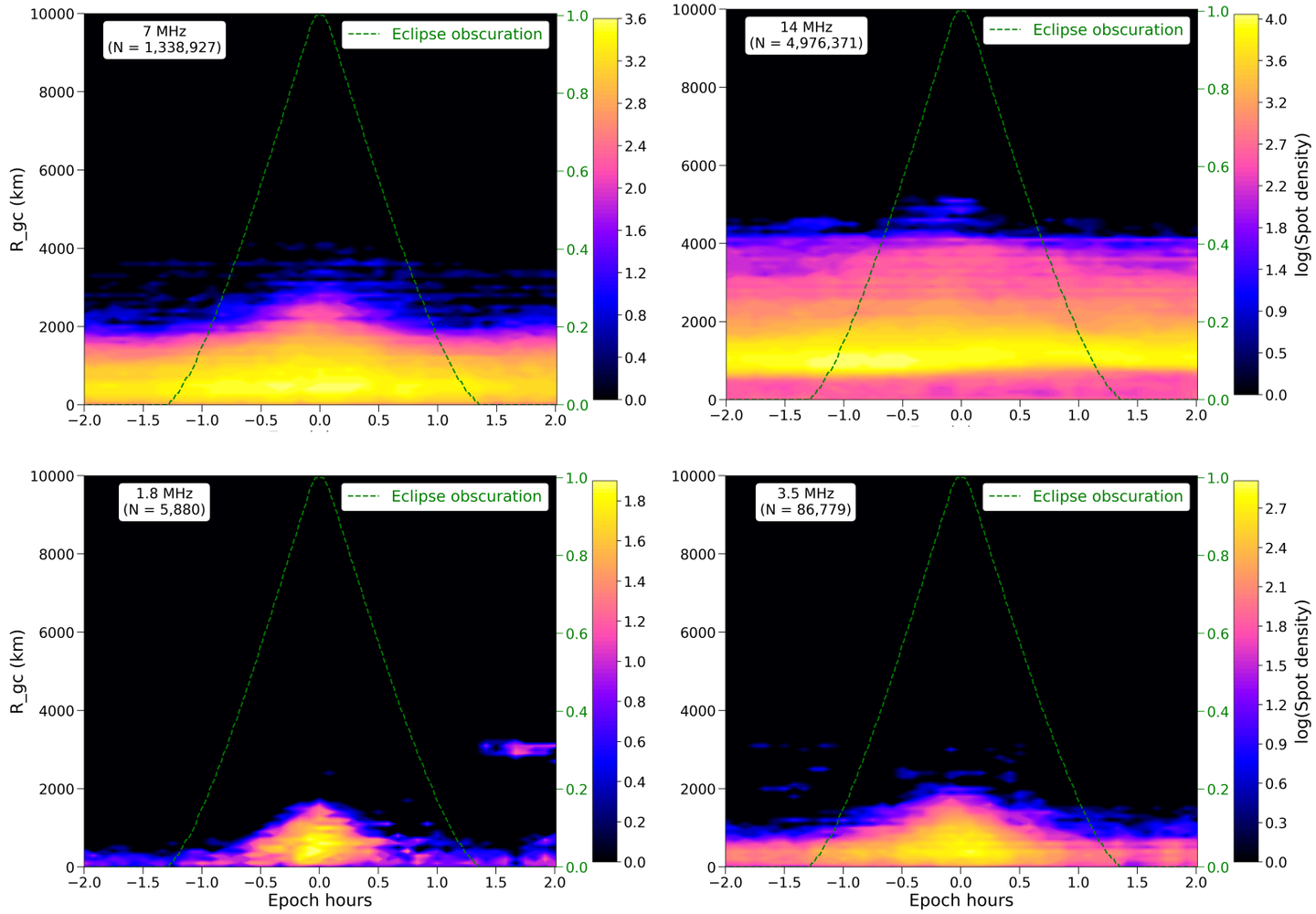


(Frissell et al., GRL 2018)

April, 8 2024

SEQP PSKReporter, WSPRNet, and RBN Observations

- **1.8 - 7 MHz (160 - 40 m):** similar responses
- **14 MHz (20 m):** different responses in 2017 & 2024, connected in 2024 with increased range?



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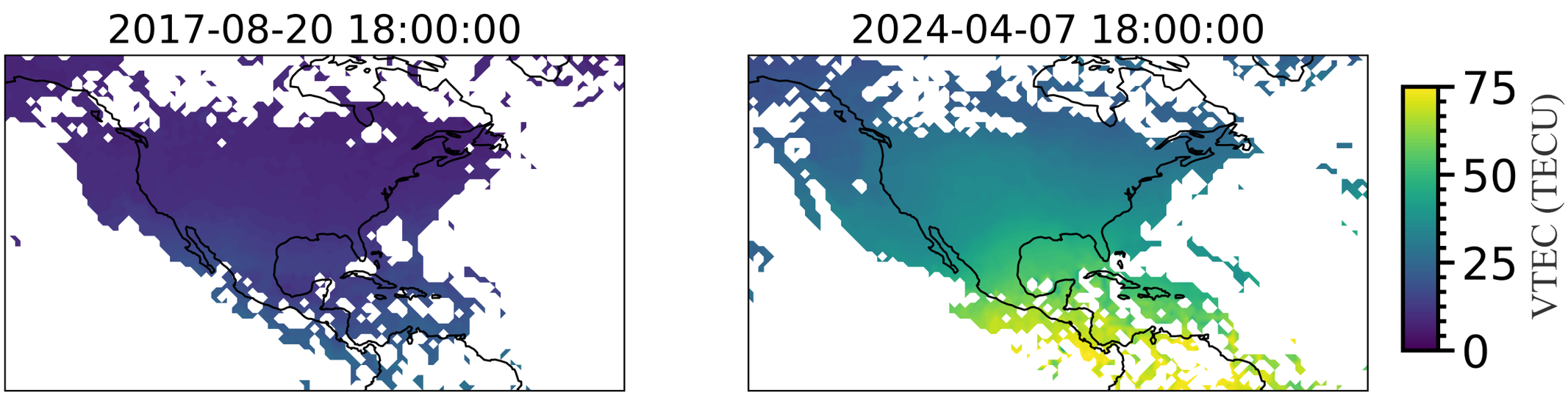
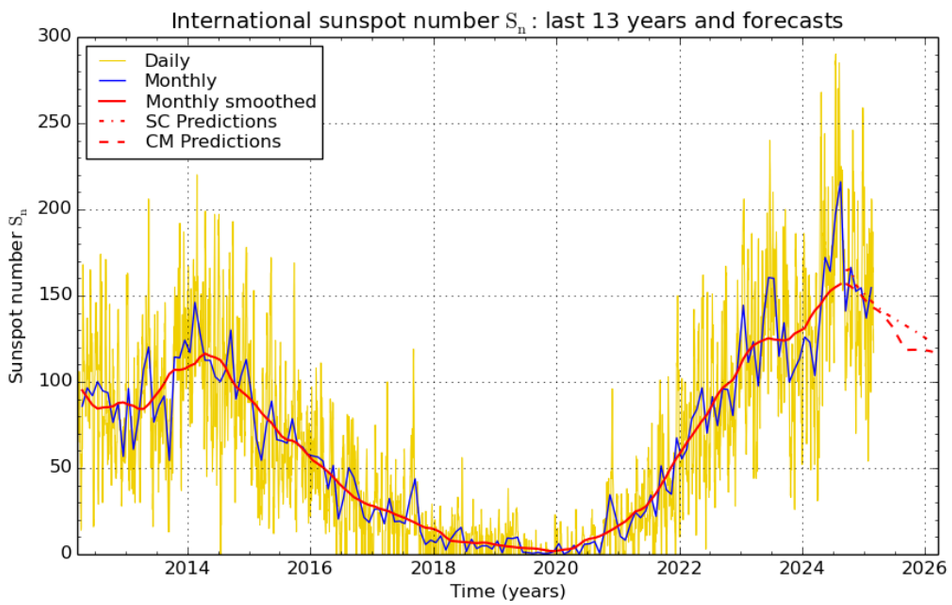
Comparison: Eclipse 2017 & 2024

- **1.8 - 7 MHz (160 - 40 m):** similar
- **14 MHz (20 m):** different responses in 2017 & 2024, connected in 2024 with increased range?
  — primarily, due to differences in solar flux level/ sunspot numbers



(Madrigal database at Millstone)

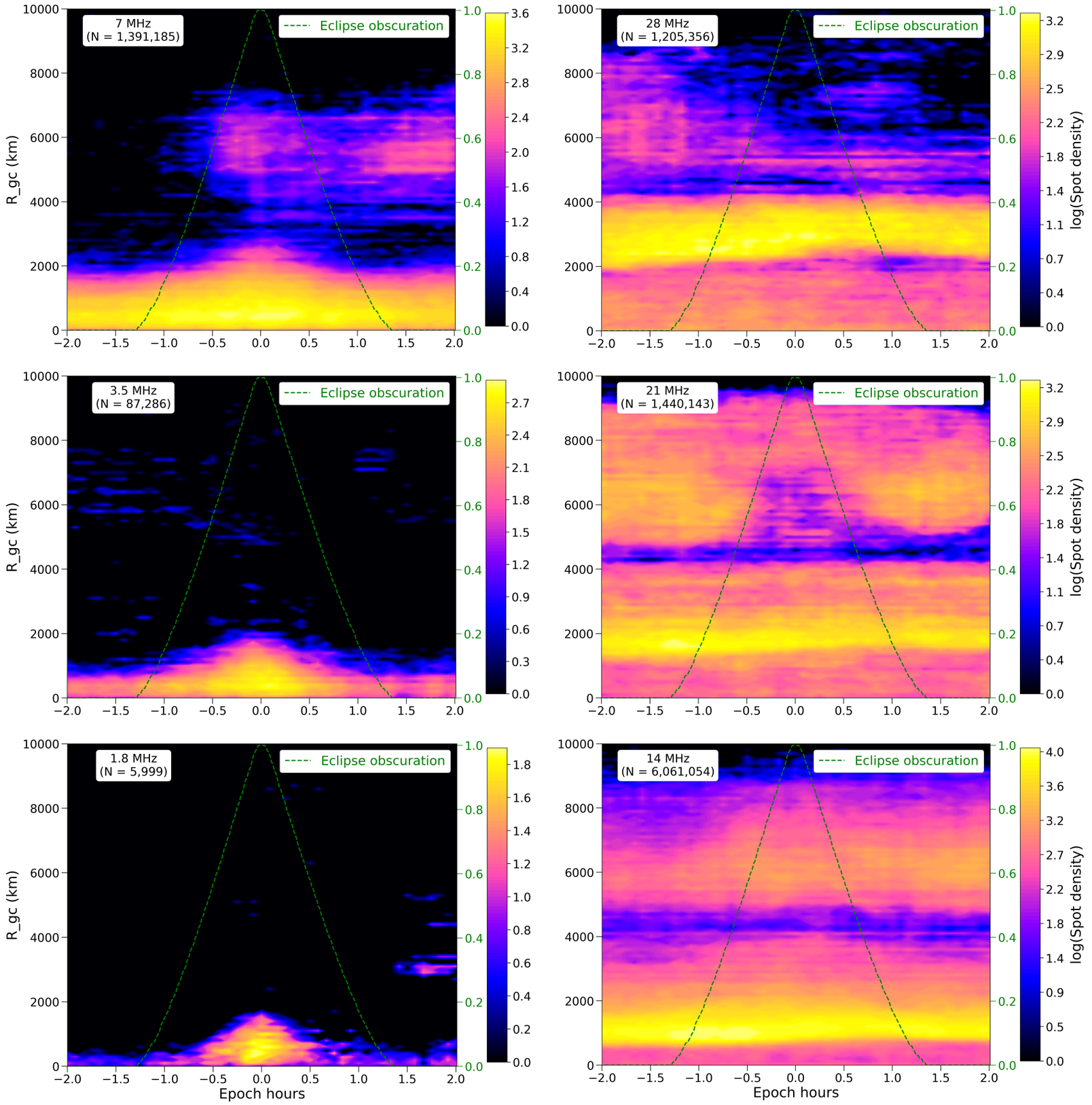


Epoch Analysis…

Epoch Analysis…

Fig: Epoch analysis with ham radio stations around the globe

CONUS features (previous fig)
+
radio links at ranges > ~4000 km
(mostly, US ◄——► Europe)



7 MHz (40 m):

- opening up of longer range links
- asymmetric response

21 MHz (15 m):

- decrease in communications
- symmetric responce

28 MHz (10 m):

- bite-out of longer range links
- asymmetric response

Spot Density: Continually Operated Tx-Rx

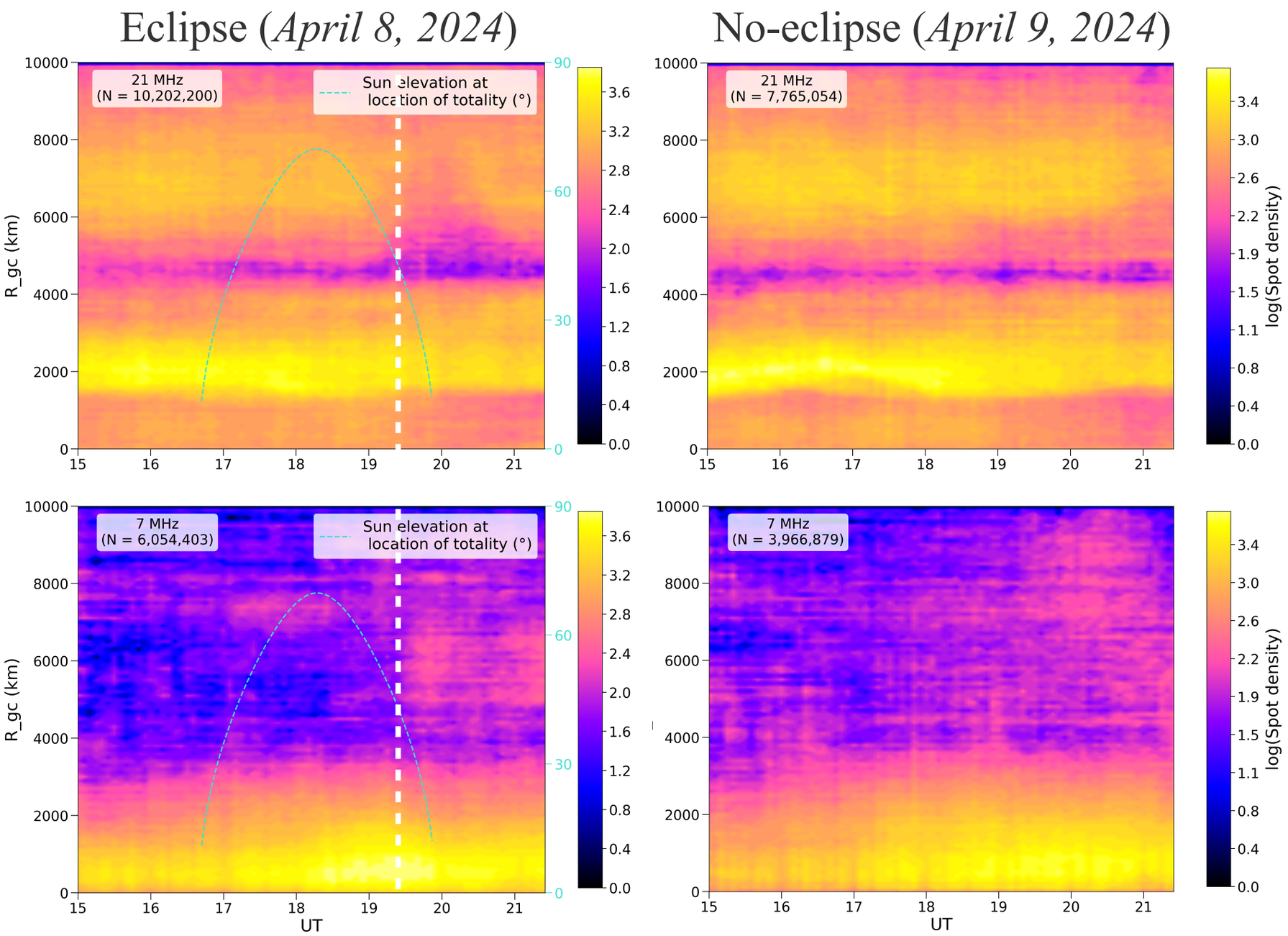


Fig: spots density with continually operated Tx and Rx stations only

Changes at longer ranges (~6000 km)

- **appeared after 19:30 UT**
- not during the entire eclipse interval!

Combined Effect of Eclipse & Sunset ?

- Changes at longer ranges (~6000 km) appeared after 19:30 UT, not during the entire eclipse interval!

? Is it due to extended shadow like conditions (eclipse + sunset)

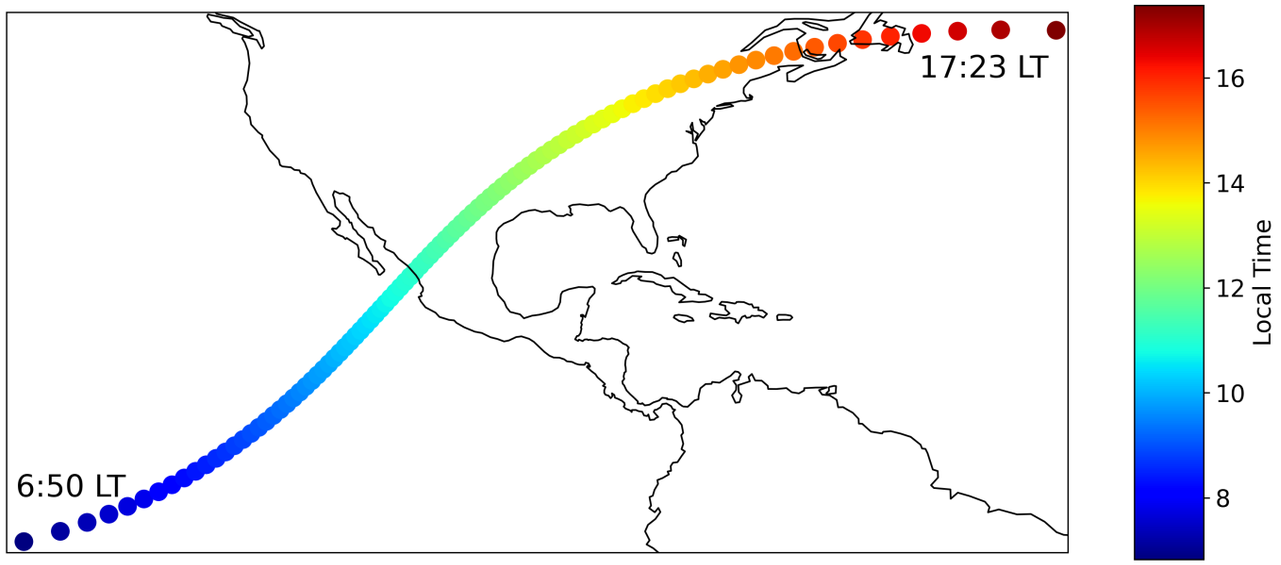


Fig: eclipse track with local time

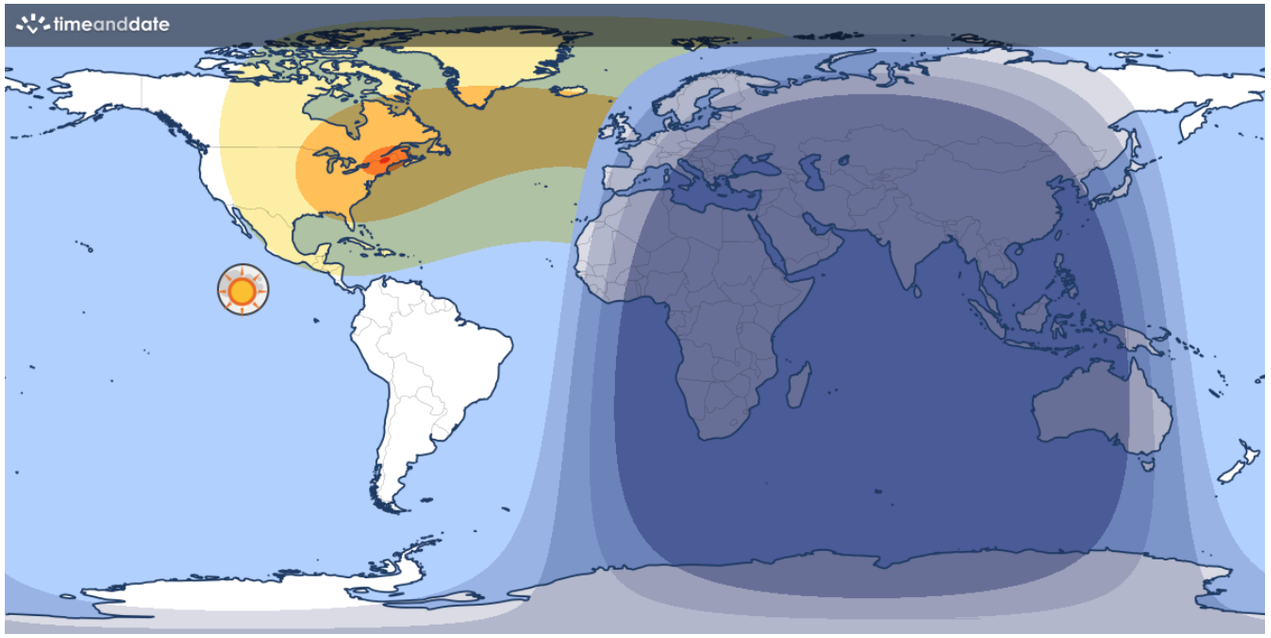


Fig: eclipse shadow at 19:30 UT + day-night conditions

https://www.timeanddate.com

Model: Raytracing

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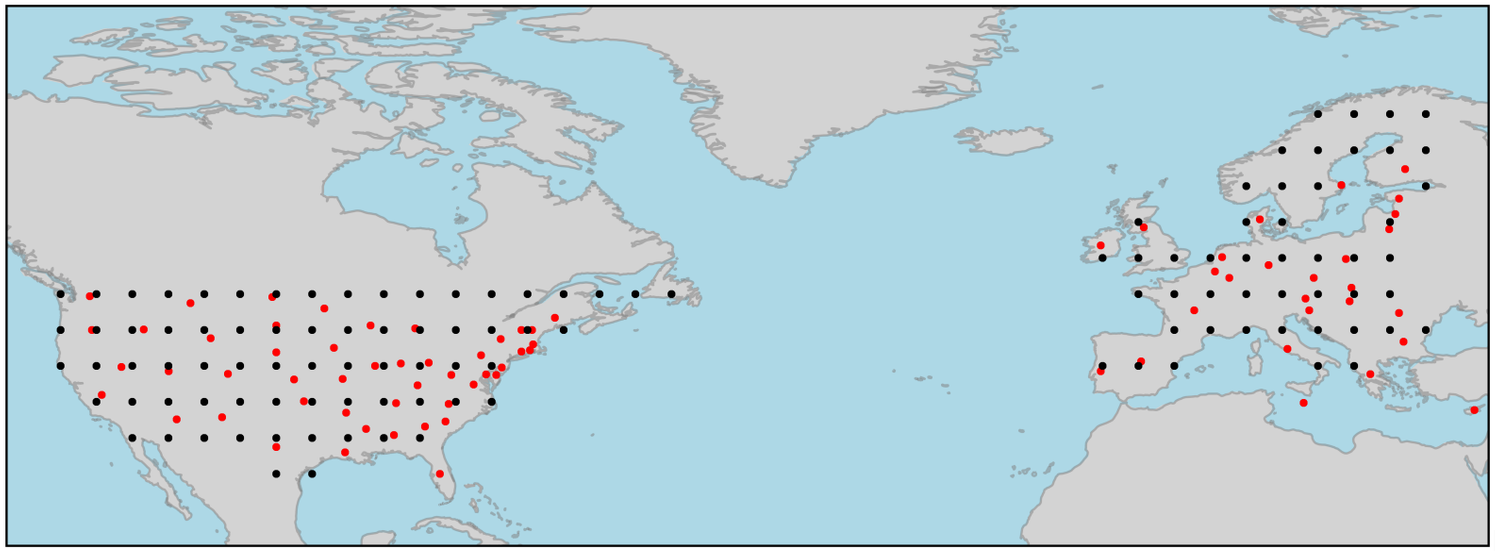

Fig: Grid of **Tx** and **Rx** stations used for raytracing

Modeling

- Ionosphere: SAMI3
  (*a physics based 3D model*)
- Raytrace: PHaRLAP
  (*Provision of High-frequency Ray tracing LAboratory for Propagation studies*)

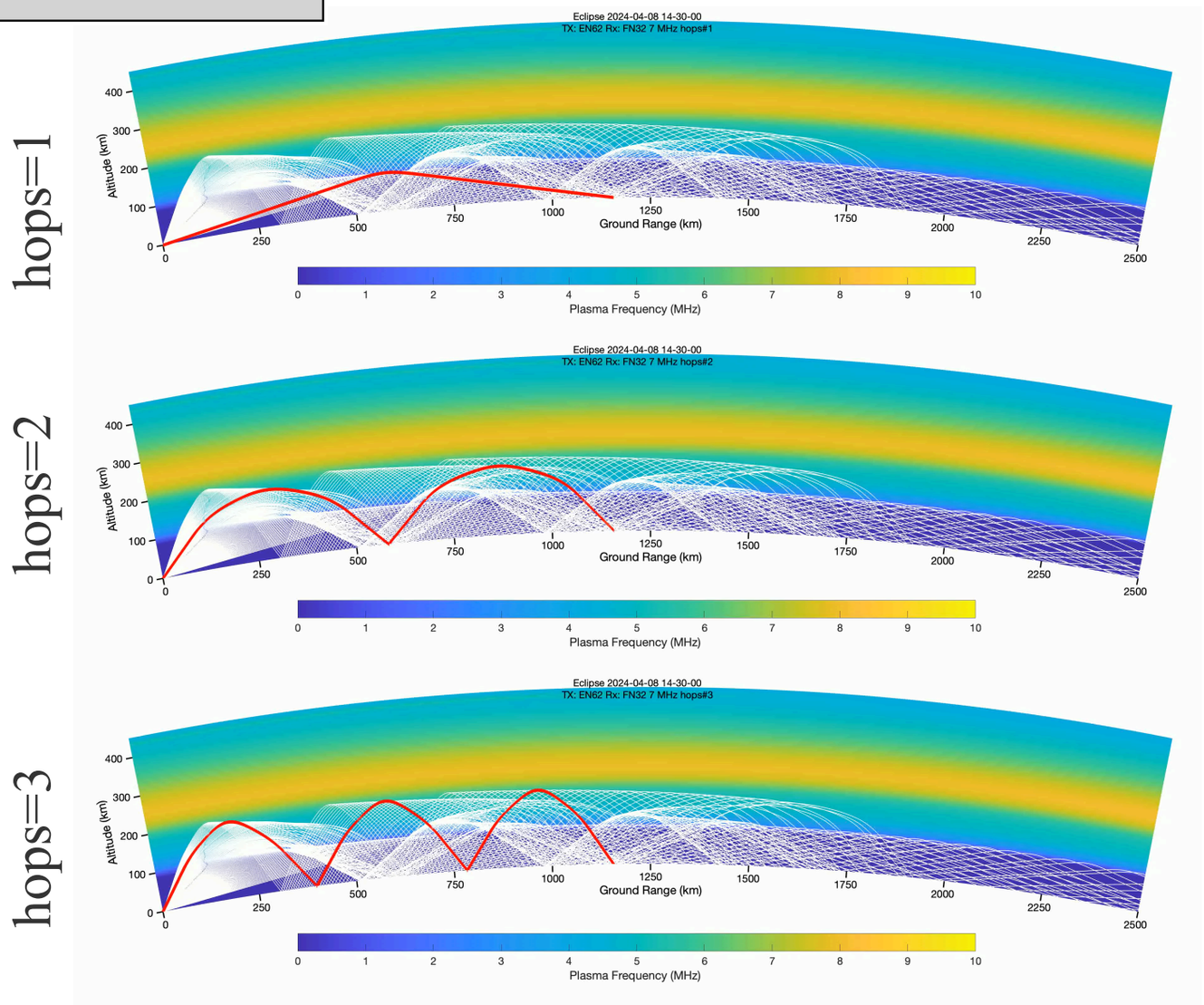

Fig: Example of modeled raytraces

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Rays with apogee < 125 km

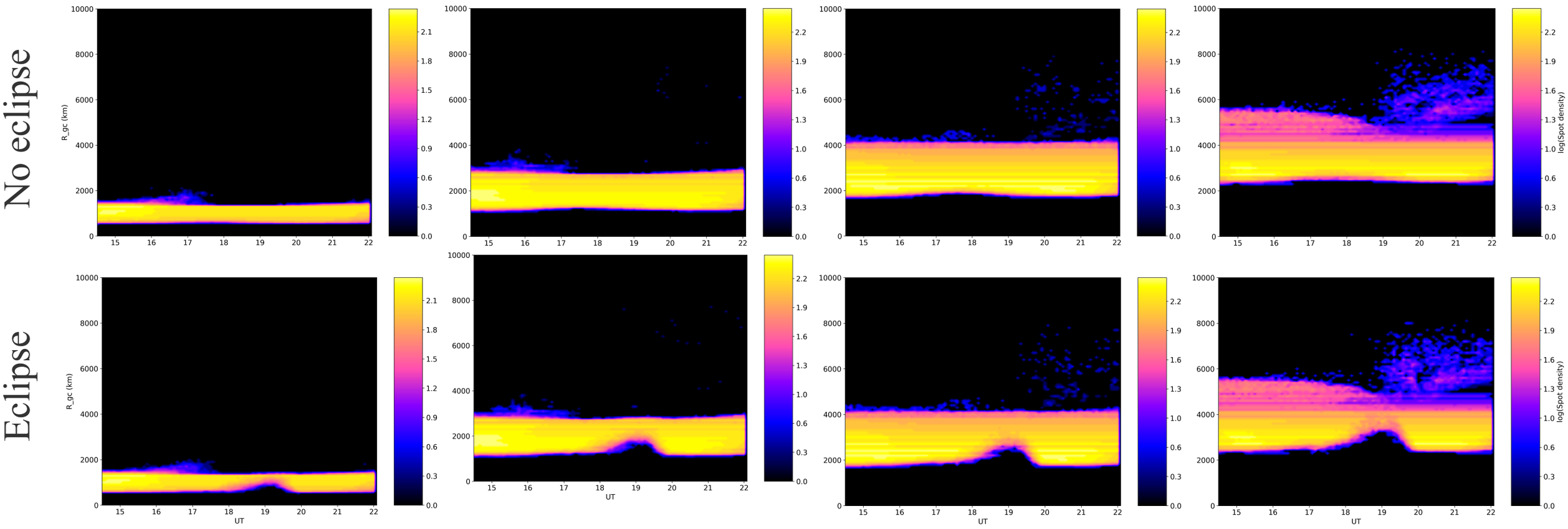

Fig: model outputs for spot density using rays with apogee > 125 km

Eclipse effects on 7 MHz (40 m): top v/s bottom panels

✓ ranges below 4000 km: all hops show increase in range of communications *(brighter color)*

✓ ranges above 4000 km: no change

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Rays with apogee ≥ 125 km

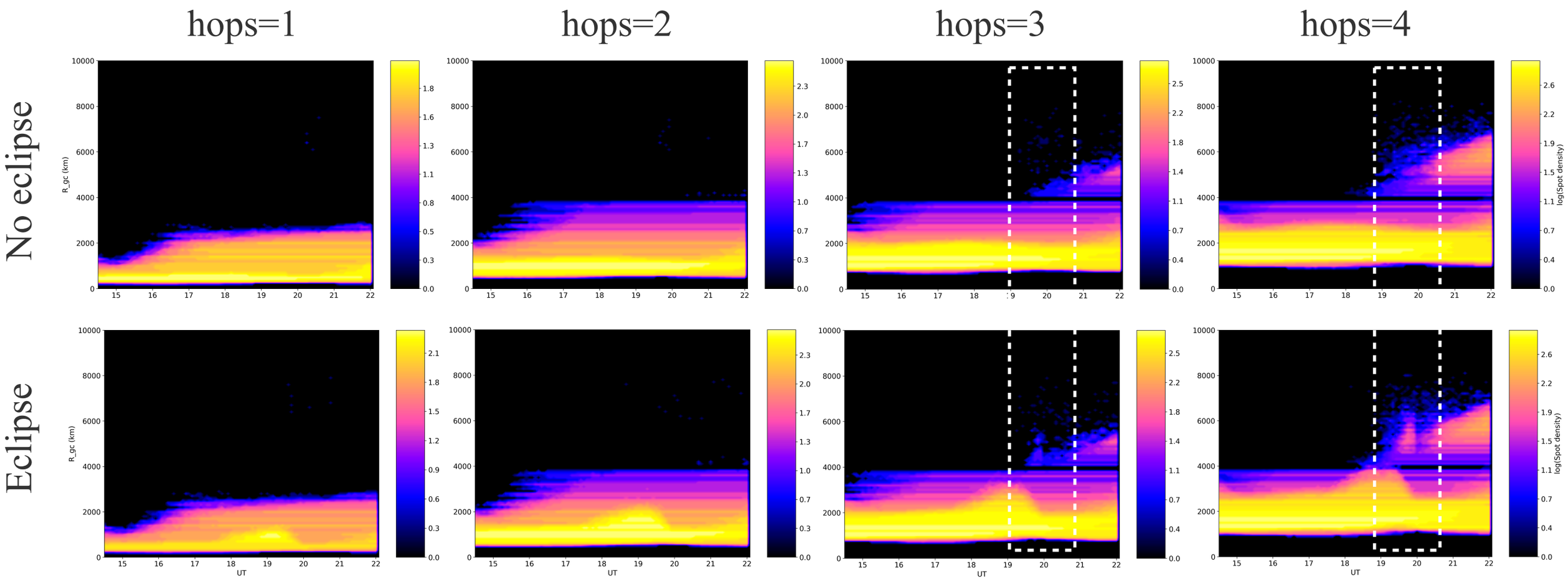

Fig: model outputs for spot density using rays with apogee ≥ 125 km

Eclipse effects on 7 MHz (40 m): top v/s bottom panels

✓ ranges below 4000 km: all hops show increase in communications and ranges *(brighter color)*

✓ ranges above 4000 km: 3 and 4 hops show earlier opening up of radio links (*notch ~19:30 UT*)

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Comparison: Data & Model

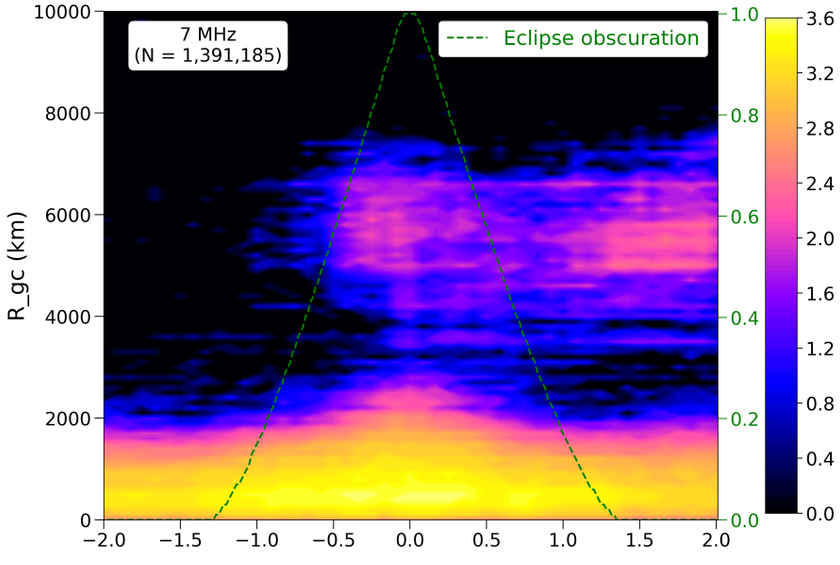
Data

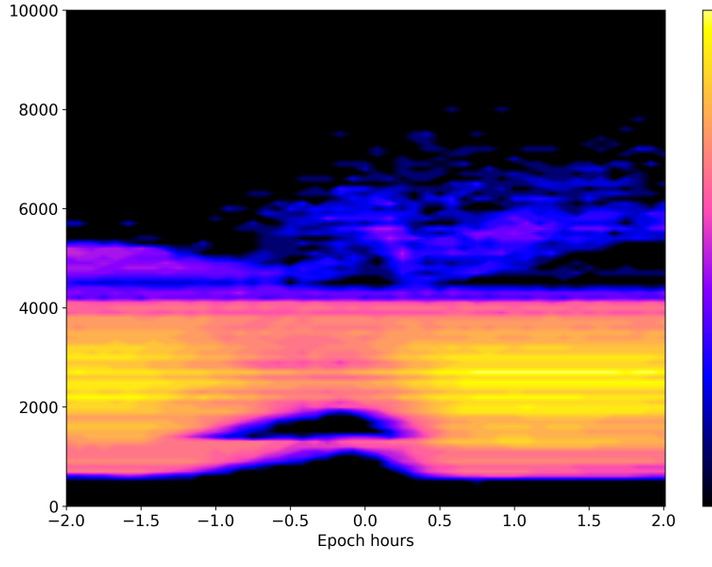
Model (1–4 hop rays combined)

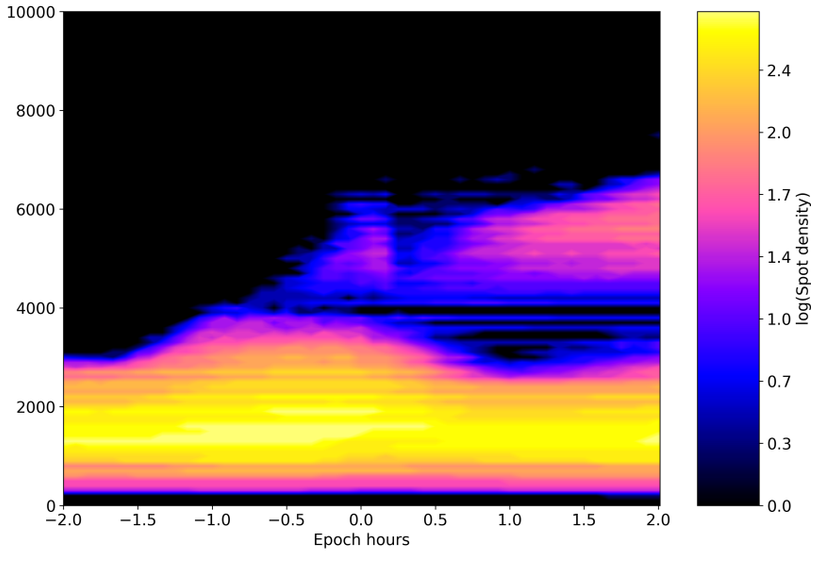
(apogee < 125 km)

(apogee ≥ 125 km)

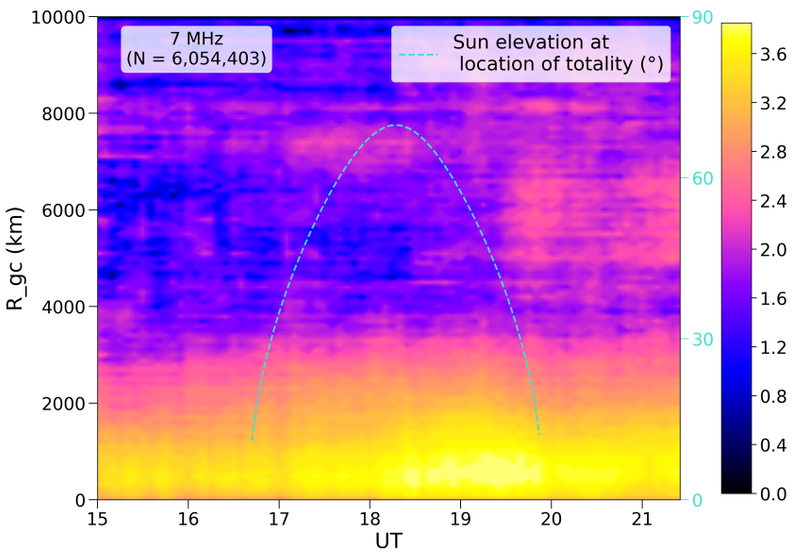
Epoch analysis

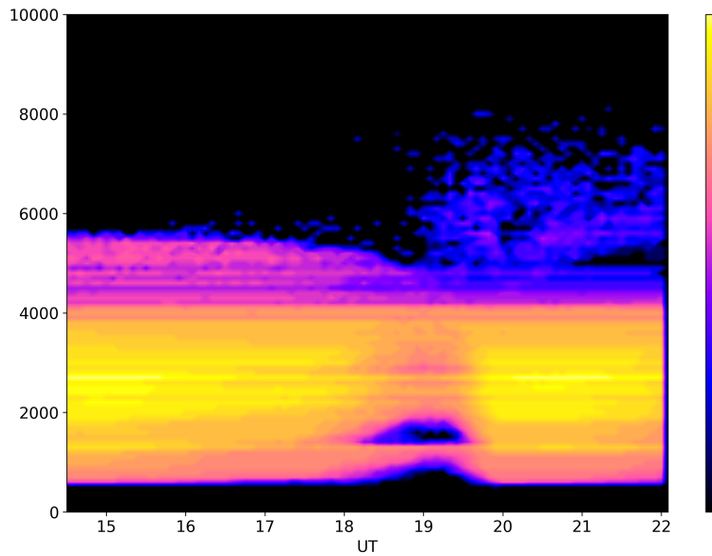


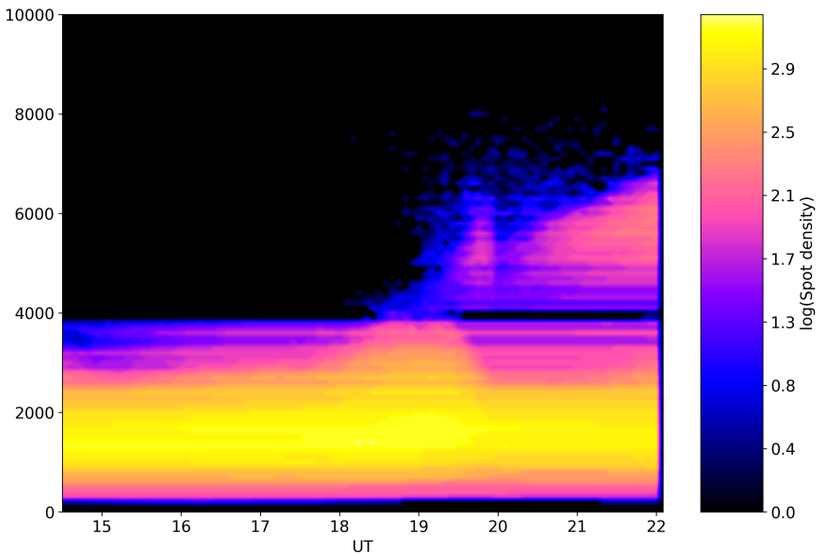




Spots: continual stations







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Combined Effect of Eclipse & Sunset ?

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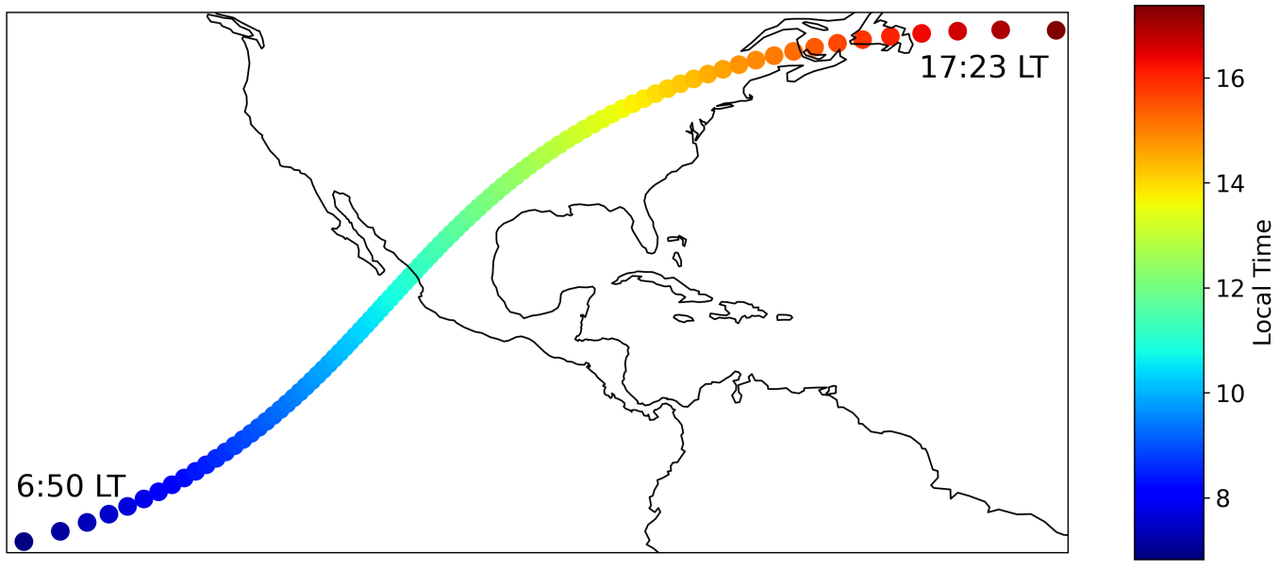
✓Is it due to extended shadow like conditions (eclipse + sunset): Yes



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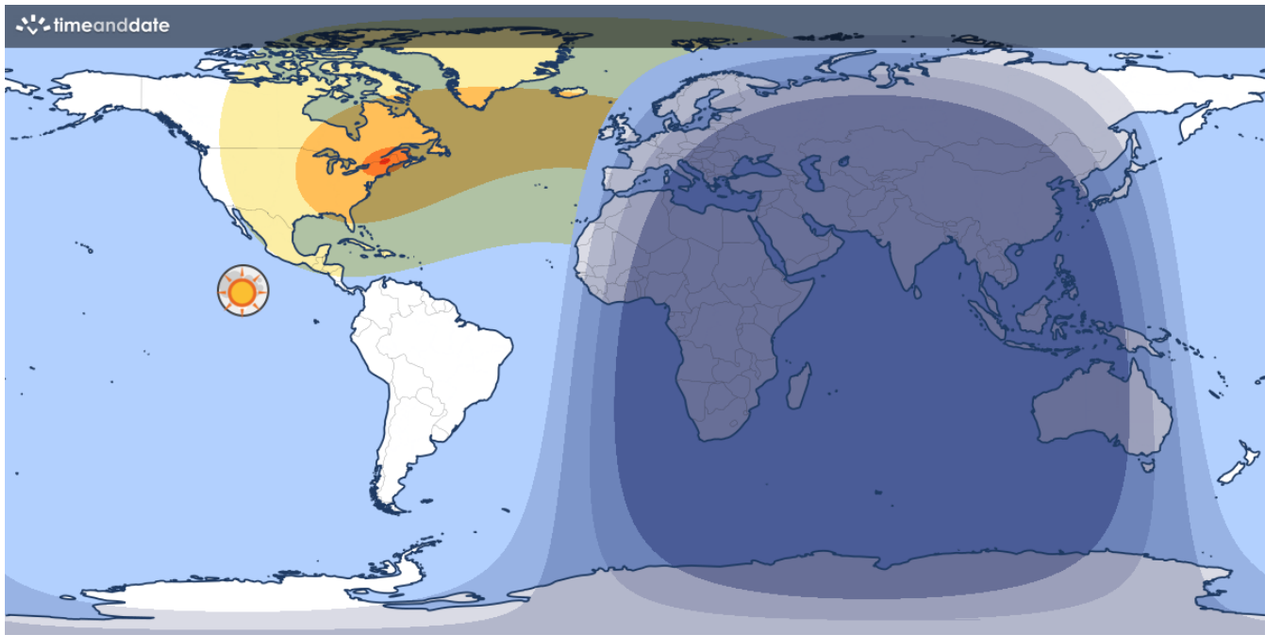

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Summary

Ham radio links within CONUS (range < 4000 km)

- 1.8 - 7 MHz (160 - 40 m): increase in range of communications, symmetric response to eclipse
- 14 - 28 MHz (20 - 10 m): increase in range of communications, delayed response to eclipse
  - *Enhanced propagation suggestive of reduced D-region absorption*
  - *Suggestive of eclipse effects symmetric and instantaneous in E-region, delayed in F-region*

- 14 MHz (20 m) response different from 2017 eclipse
  - *Likely, due to different ionospheric levels (Solar cycle - Sunspot number change)*

Ham radio links between US and Europe (range ~6000 km)

- Eclipse effects appeared ~19:30 UT, not during the entire eclipse interval
  - ✓ *Earlier opening of 7 MHz band of communications*
  - ✓ *Combined effect of eclipse + sunset (extended shadow like condition)*
  - *Reduced connectivity at 21 MHz, bite-out of 28 MHz links*

Acknowledgements

NASA grant 80NSSC23K1322, NSF grants AGS-2045755, AGS-2230345, AGS-2230346, Ham Radio community

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http://hamsci.org

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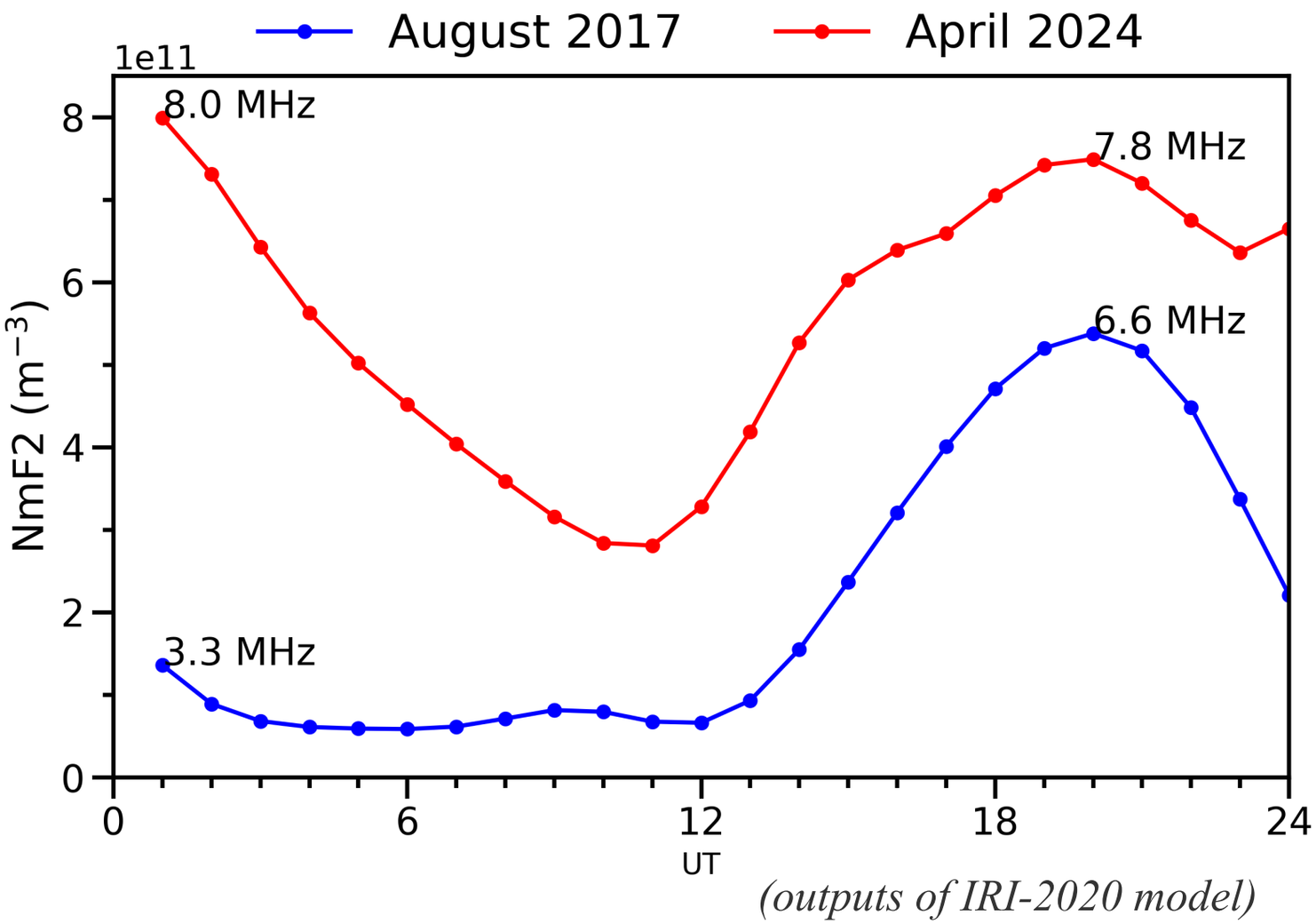

(outputs of IRI-2020 model)